Publication 5002

AGRICULTURAL MATERIALS HANDLING MANUAL

PART 2 CONVEYORS

SECTION 2.1

CHAIN AND BELT CONVEYORS

Agriculture
Canada

Publication 5002

AGRICULTURAL MATERIALS HANDLING MANUAL

PART 2 CONVEYORS

SECTION 2.1

CHAIN AND BELT CONVEYORS

The Agricultural Materials Handling Manual is produced in several parts as a guide to designers of materials handling systems for farms and associated industries. Sections deal with selection and design of specific types of equipment for materials handling and processing. Items may be required to function independently or as components of a system. The design of a complete system may require information from several sections of the manual.

L.M. STALEY
DEPT. OF BIO-RESOURCE ENGINEERING
UNIVERSITY OF BRITISH COLUMBIA
VANCOUVER, B.C.

originally compiled by

J. POS
SCHOOL OF ENGINEERING
UNIVERSITY OF GUELPH
GUELPH, ONT.

PREPARED FOR THE CANADA COMMITTEE ON AGRICULTURAL ENGINEERING
OF
CANADIAN AGRICULTURAL SERVICES
COORDINATING COMMITTEE

Copies of this publication may be obtained from
INFORMATION DIVISION
CANADA DEPARTMENT OF AGRICULTURE
OTTAWA
K1A 0C7

1.5M—7:77

TABLE OF CONTENTS

FIGURES

TABLES

LIST OF SYMBOLS

a - cross sectional area (m^2)
b - bulk density (kg/m^3)
C - capacity m^3
c - coefficient of loading
d - diameter (m)
e - efficiency
F_c - centrifugal force (N)
F_e - force to move empty conveyor (N)
g - acceleration of gravity (9.81 m/s^2)
H - elevation change or height (m)
k - loading factor for augers
L - length of conveyor (m)
L_c - assumed extra length of conveyor to compensate for friction
M - mass of material
M_m - mass of material conveyed (kg)
M_p - mass of sliding parts of conveyor (kg)
n - rpm or rps
P - power (W)
P_e - power for driving empty conveyor (W)
P_m - power for moving material conveyed (W)
P_r - power for elevating material (W)
R - effective radius of centre of rotation (m)
S - spacing (m)
T - capacity of conveyor (kg/s)
v - volume (m^3)
V - velocity (m/s)
w - width of conveyor (m)
μ - tangent of angle of repose
μm - coefficient of friction between material and conveyor
μp - coefficient friction between flights on bottom of conveyor

SECTION 2.1 CHAIN AND BELT CONVEYORS

2.1.1 *General*

Agricultural material conveyors are used for carrying, pushing or guiding fluids, slurries or solids. Conveyor selection depends on the quantity and characteristics of the conveyed material, the conveyor capacity required, the environmental operating conditions, the mechanical characteristics of the conveyor and economics.

The mechanical and physical characteristics of agricultural materials are given in Section 7.1. Mechanical characteristics of the conveyor units are discussed in subsequent sections of Part 2. The pertinent environmental and economic constraints of the particular application should also be evaluated prior to the selection of equipment.

Chain, belt and auger conveyors have been designed to convey free flowing materials as well as to serve as bunk feeders for distributing hay, silage and grain to livestock and poultry. A comparative assessment of these units is given in Section 2.1.4. Belt and flight conveyors are also widely used to convey packaged material such as bales and sacks.

Chain conveyors are frequently selected for agricultural use because of their simplicity and relatively low initial cost. They are not as quiet in operation as other types of conveyors but this is usually not a serious disadvantage since their operation will likely be intermittent.

Chain and flight conveyors can move material either horizontally or on slopes up to 45^{o}. Over 45^{o} there is a serious reduction in capacity unless special modifications are made, some of which are discussed in this and other sections of Part 2.

Flight conveyors can have large volumetric capacity compared to other types of conveyors and are relatively gentle acting on conveyed material. Chain and flight conveyors achieve maximum capacity per unit of power input for handling coarse or fibrous materials. For smooth and free flowing material auger or belt conveyors are a better choice. Based on capacity their initial and maintenance costs are low.

Operating speeds of chain and flight conveyors are normally below 1.2 m/s (240 ft/min). Segregation of material of different sizes and densities such as mixed feed rations of silage and grain may occur. Therefore adequate mixing of feed rations should occur before the material is conveyed by flight conveyors.

To analyze the performance of an en-masse and chain conveyor the following parameters are required:

a) Weight of chain and flight per unit length.
b) Coefficient of friction between the moving and stationary parts of the conveyor.
c) Coefficient of friction between the conveyed material and the conveyor trough.
d) The length of the conveyor.
e) The quantity of material to be moved per unit of time.
f) The difference in elevation between the points of loading and unloading the conveyor.

2.1.2 *Drag Chain Conveyors*

These conveyors may have one or more endless chains to which flighting is mounted to drag bulk materials in a trough. Its primary use is in handling abrasive or fibrous material such as silage and hay for cattle feeding bunks and barn gutter cleaners. Its use is mostly confined to horizontal installations but inclines of up to 20^{o} are used. For inclines over 20^{o} special flights are required.

Modifications to the drag chain conveyor by some manufacturers has made its use more widespread for handling grains and other free flowing materials. By changing the cross section of the scrapers and employing materials such as tough plastics these conveyors will handle large volumes without tumbling or degradation. They are relatively dust free, provided the cohesion between particles is greater than the frictional resistance between the conveyed material and the enclosure. An example of one such commercial unit is shown in Figure 2.1.1. Capacities and power requirements of a commercial drag chain conveyor are given in Table 2.1.1.

2.1.2.1 *En Masse Conveyor*

When one strand of the conveyor cable or chain, with attached flights, is enclosed in a close fitting casing the full cross section of the enclosure will be filled with material. This conveyor can operate effectively at any incline including the vertical.

This principle has been further modified to provide a feed distribution system in poultry and swine buildings. Plastic buttons are attached to a steel cable which is pulled through steel tubing ranging in size from 38 to 60 mm (1½ to 2½ in) diameter. Speed of operation is normally less than 0.6 m/s (120 ft/min) to avoid air entrainment and dust formation. An example of one such commercial unit is shown in Figure 2.1.2. Typical delivery rates, lengths and power requirements are presented in Table 2.1.2.

2.1.2.2 *Capacity of Drag Conveyors*

The maximum capacity of the ordinary drag conveyor is reached when the depth of material is equal to the width of the chain. These units have a high capacity in relation to their size. Power requirements are about half that for auger conveyors but slightly greater than for flight conveyors, (see Section 2.1.3). The speed is usually limited to about .3 m/s (60 ft/min). The transport capacity may be estimated from

$$T = abVc \qquad [1]$$

where T = capacity (kg/s)
a = cross section area of conveyed material (m^2)
V = speed (m/s)
b = bulk density of conveyed materials (kg/m^3)
c = coefficient of loading usually .7 to .77. See Table 2.1.3 for other values.

2.1.3 *Chain and Flight Conveyors*

Flight conveyors consist essentially of one or more chains or cables to which flights or scraper blades are attached. The flights, which slide in a trough, drag material along its length. Various proprietory names are attached to

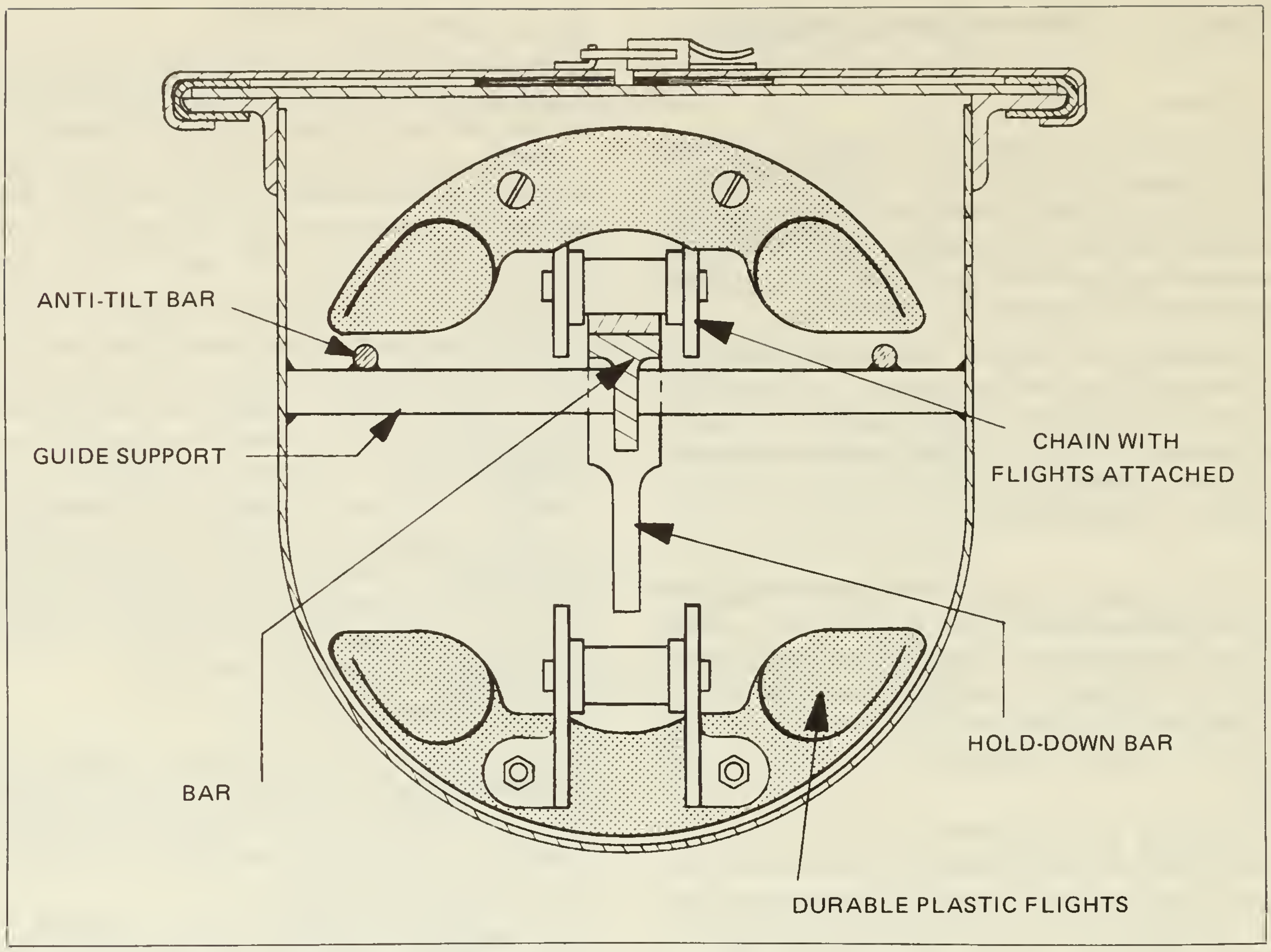


FIGURE 2.1.1 Drag-Flo Chain Conveyor. Courtesy: Sullivan Strong Scott

TABLE 2.1.1 DRAG-FLO CONVEYOR – CAPACITY AND POWER REQUIREMENTS

SIZE	Vol/hr @ .5 m/s	Vol/hr @ .6 m/s	Vol/hr @ .8 m/s	POWER PER METER .5 m/s	.6 m/s	.8 m/s	"C" COMBINATION CHAIN Max power @ .5 m/s	Max power @ .8 m/s	"SS" STEEL CHAIN Max power @ .5 m/s	Max power @ .8 m/s
mm	m^3	m^3	m^3	W	W	W	kW	kW	kW	kW
150	30.6	38.2	45.8	10.4	12.6	15.0	4.0	6.0		
230	55.2	69.1	82.9	19.3	24.6	30.0	4.0	6.0		
300	87.5	109.3	131.0	29.8	37.2	45.0	6.0	7.0	7.0	11.0
360	117.5	147.0	176.3	41.0	51.4	62.0	6.0	7.0	7.0	11.0
410	150.9	188.8	226.8	51.4	64.1	76.8	6.0	7.0	7.0	11.0
460	189.7	237.0	284.3	64.1	79.0	95.4	6.0	7.0	7.0	11.0
510	233.3	291.6	350.0	83.5	104.0	126.0	11.0	15.0	15.0	22.0
610	320.5	400.9	481.0	110.3	138.0	165.5	11.0	15.0	15.0	22.0

SIZE	Vol/hr @ 100 ft/m	Vol/hr @ 125 ft/m	Vol/hr @ 150 ft/m	POWER PER FT 100 ft/m	125 ft/m	150 ft/m	"C" COMBINATION CHAIN Max power @ 100 ft/m	Max power @ 150 ft/m	"SS" STEEL CHAIN Max power @ 100 ft/m	Max power @ 150 ft/m
in	ft^3	ft^3	ft^3	hp	hp	hp	hp	hp	hp	hp
6	1,080	1,350	1,620	.01	.02	.02	5	7½		
9	1.950	2,440	2,930	.03	.03	.04	5	7½		
12	3,090	3,860	4,630	.04	.05	.06	7½	10	10	15
14	4,150	5,190	6,230	.05	.07	.08	7½	10	10	15
16	5,330	6,670	8,010	.07	.09	.10	7½	10	10	15
18	6,700	8,370	10,040	.09	.11	.13	7½	10	10	15
20	8,240	10,300	12,360	.11	.14	.17	15	20	20	30
24	11,320	14,160	17,000	.15	.18	.22	15	20	20	30

(Adapted from Sullivan Strong Scott Catalogue)

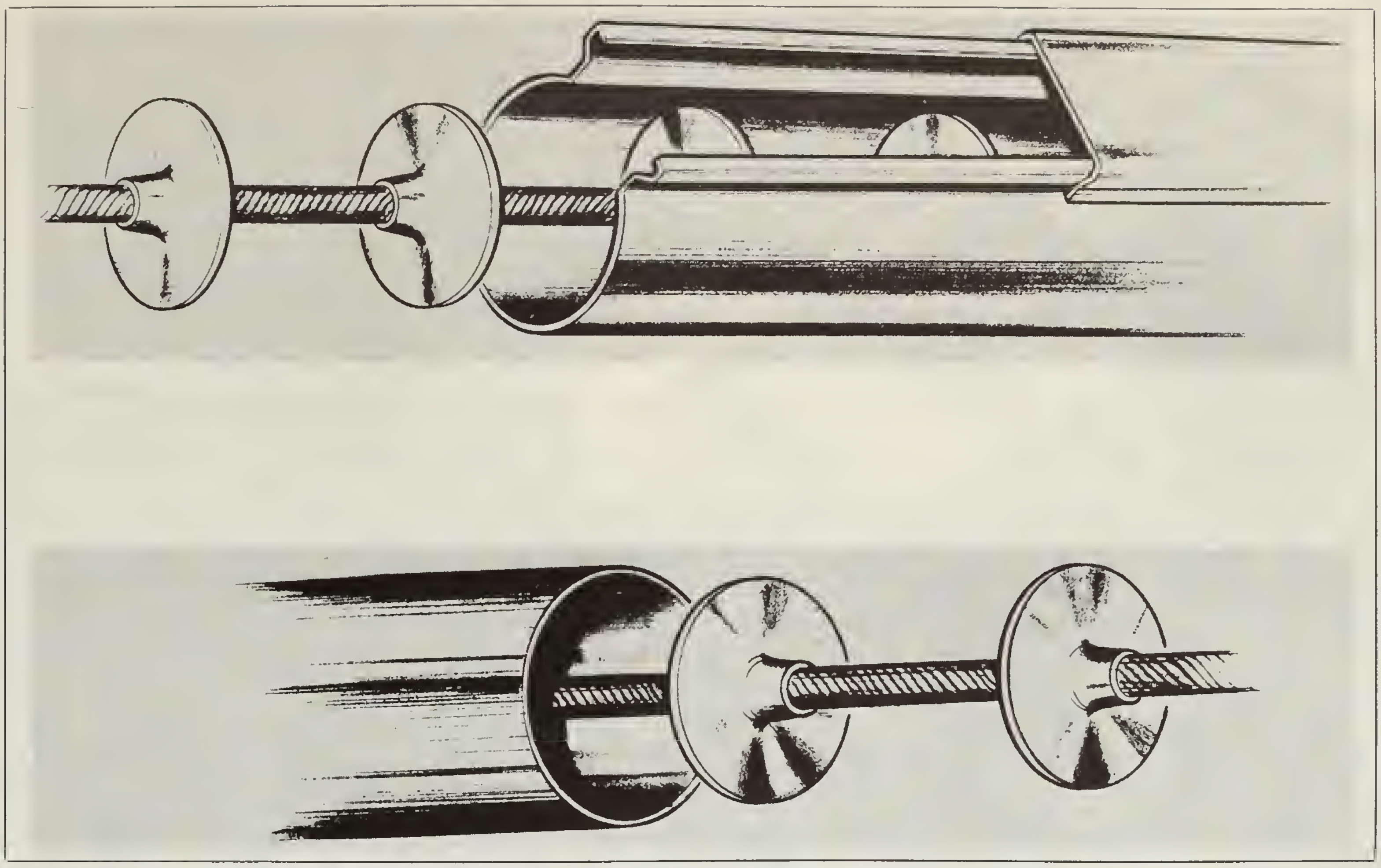


FIGURE 2.1.2 En Masse Conveyor. Courtesy: Fairfield Engineering and Manufacturing Company.

TABLE 2.1.2 RECOMMENDED DELIVERY RATES, LENGTH AND POWER REQUIREMENTS FOR CABLE TYPE EN-MASSE POULTRY FEEDER CONVEYOR

Cable Speed ft/min	Approx. Delivery Rate lb/hr 30 mm	60 mm	Recommended Lengths ft*	hp
50-55	750-825		1200-1500	1-1½
80-85	975-1050		900-1200	1-1½
		3740	300-500	2-3
90-95	1350-1425		600	1
		4312	300	2

*Recommended length is dependent on distance feed is pulled and number of corners which are limited to 18 for the 38 mm size and 10 for the 60 mm size.

Coefficients for use in equation [1] are given in Table 2.1.3.

TABLE 2.1.3 COEFFICIENT FOR ESTIMATING CHAIN AND FLIGHT CONVEYOR CAPACITIES OPERATING AT VARIOUS INCLINES

Incline °	Coefficient c
0	1.15
20	0.77
30	0.55
40	0.33

conveyors with specially designed shapes of flights, trough cross section and propelling media.

Flight conveyors of various types, sizes and capacities can be obtained by consulting manufacturers' catalogues. Therefore in selecting a conveyor ensure that it fits in with the overall material handling system and is the best conveyor for the material handled.

2.1.3.1 *Capacity and power requirements*

Capacities can be calculated using equation [1]. For conveyors operating at an incline capacities are reduced.

Three components make up the power requirements for conveyors:

a) The power to drive the empty conveyor.
b) The power to convey the material.
c) The power to raise or lower the material.

The mass of chain and flights and the coefficients of friction between the flights and conveyor trough influence the power required to drive the empty conveyor. Typical coefficients of friction for various materials are given in Table 2.1.4.

FIGURE 2.1.3 Portable Flight Conveyor. Courtesy: Kewanee Machinery Division Chromalloy American Corp.

TABLE 2.1.4 COEFFICIENT OF SLIDING FRICTION μ*

Material	μ
Metal on wood	0.5-0.6
Cast iron on mild steel	0.23
Grain on rough board	0.30-0.45
Grain on smooth board	0.30-0.35
Grain on iron	0.35-0.40
Steel on steel	0.57
Malleable roller chain on steel	0.35
Roller-bushed chains on steel	0.20

*See Section 7.1 for additional materials.

The force required to drive the conveyor and its contents is

$$F = (M_p\ L\ g\ \mu_p) + (M_m\ L\ g\ \mu_m) + (\frac{T}{V}\ g\ H) \qquad [2]$$

where F = draft force (N)

M_p = mass of sliding parts (kg/m)

g = gravitational constant (9.81 m/s)

μ_p = coefficient of sliding friction of the sliding parts in contact with the conveyor case

L = length of conveyor (m)

M_m = mass of conveyed material (kg/m)

μ_m = coefficient of friction for the material in contact with the conveyor case

H = Elevation change of the material, negative if the material is lowered (m)

The power required to drive the conveyor may be estimated from:

$$P = \frac{FV}{e} \qquad [3]$$

where P = power required (W)

V = conveyor chain velocity (m/s)

e = drive efficiency. For most agricultural applications this may be estimated at 0.5. For well designed drives operating on antifriction bearings use 0.75.

2.1.3.2 Example Problem

A chain and flight conveyor is to be selected to convey hay wafers in a storage building. A vertical lift of 10.5 meters at a 40^{o} incline and a throughput of 2.5 kg/s is required. From Table 7.1.4 the density of hay wafers is 40.0 kg/m^3. From Table 7.1.9 the coefficient of friction

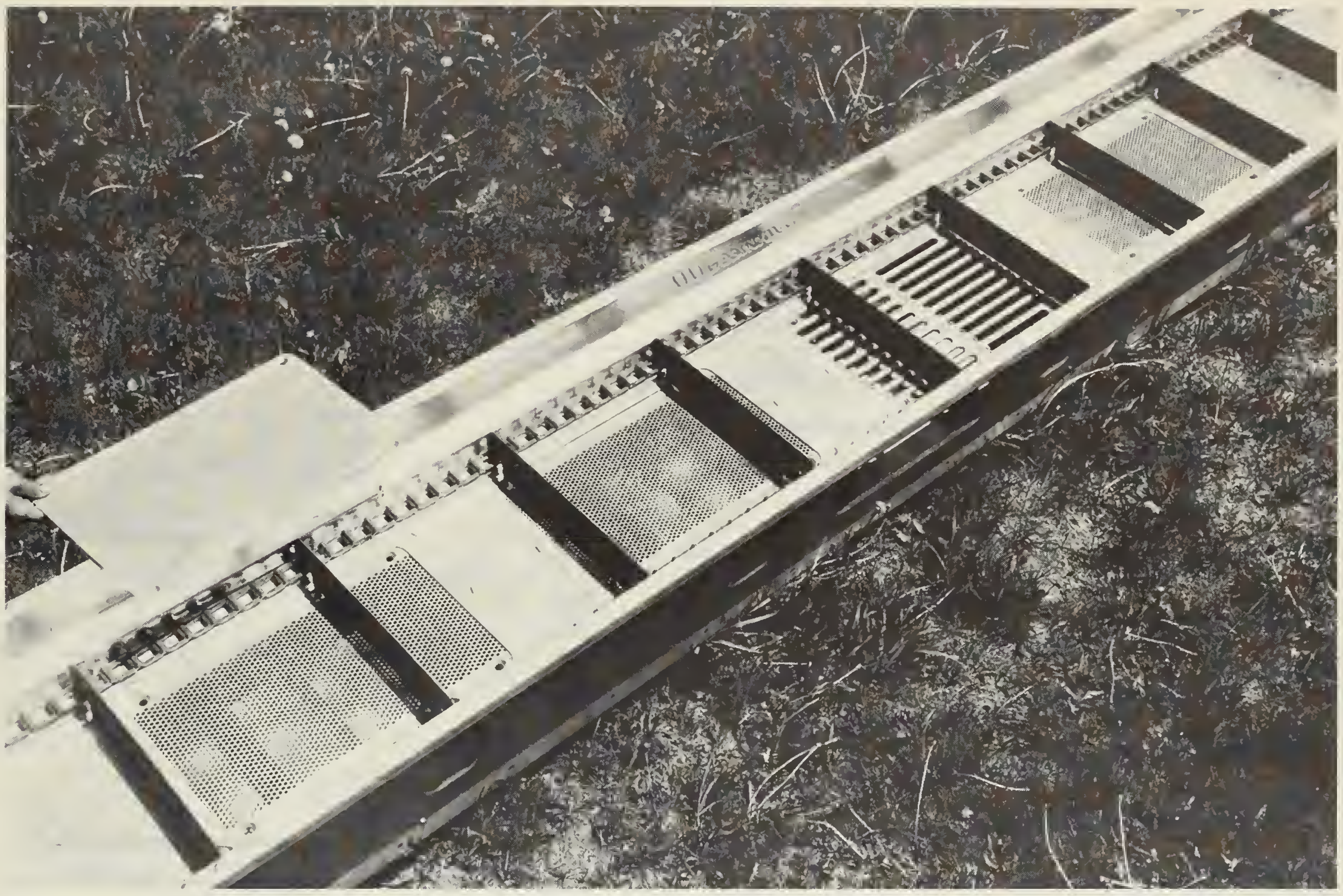


FIGURE 2.1.4 Screens to Separate Materials in Flight Conveyor. Courtesy: Kewanee Machine Division Chromalloy American Corp.

of the wafers on steel can be estimated at 0.40 (moisture content 10%). Assume an average chain speed of 0.77 m/s (see Table 2.1.5). From Table 2.1.3, and from Table 2.1.4 the coefficient of friction μ_p of steel parts on a steel trough is 0.57.

From equation [1] calculate the conveyor cross section area required,

$$a = \frac{T}{V\,b\,c}$$

$$= \frac{2.5}{.77(400)\ (.33)}$$

$$= .01\ m^2$$

A commercial unit with .36m (14 in) width and 0.4m (1.5 in) flights is 0.01 m^2 in cross section. This unit could be operated at 0.72 m/s (140 ft/min), which is slower than the flight speed listed in Table 2.1.5. However Table 2.1.5 is primarily for small grains and this lower speed would be desirable for hay wafers.

Power requirements can now be calculated. From equation [2] and [3] determine the power required to drive the empty conveyor.

$$\text{Estimate } M_p = 2.8 \text{ kg/m}$$

$$\text{Theoretical conveyor length } L = 10.5 \sin 40^o$$

$$= 16.3 \text{ m}$$

If overhang or additional clearance is required an additional 1.2 to 1.5 m should be added to the theoretical length.

$$M_m = \frac{2.5}{.72} = 3.47 \text{ kg/m}$$

$$P = \frac{[2.8(16.3)(9.81)(.57) + 3.47(16.3)(9.81)(0.4) + (2.5/.72)(9.81)10.5]\ .72}{.50}$$

$$= 1202\text{W} = 1.6 \text{ hp}$$

Therefore choose a 2 hp electric motor.

2.1.3.3 General specifications of flight conveyors

When a quick estimate of flight conveyor width, power requirement and throughput is required, Table 2.1.5 will serve as a useful guide.

Flights should be approximately 0.4 (flight length) in height and spaced the length of the flight apart for use with granular materials. Lower flights should be used for bales, sacks and ear corn. Flight material should be hardwood or steel. The conveyor should be driven through the head or discharge end.

Equation [2] gives the total pull which should be divided by the number of chains to determine the working lead on each chain. Manufacturers' catalogues usually allow for suitable safety factors. Table 2.1.6 gives some recommendations on the type of chain to use for selected applications.

TABLE 2.1.5 FLIGHT CONVEYOR SPECIFICATION

Flight Width mm	Watts required for various lengths (m) 1.5-6.1	6.4-9.1	9.4-12.2	12.5-15.2	Flight Speed m/s	Approximate Capacities m^3/hr
130	186-373	559			1.5-2.3	10.6-17.6
150*	186-559	559-746			1.5-2.3	17.6-21.1
200*	373-746	373-746	559-746		.8-1.7	14.1-21.1
360	559	746	1119-2237	1491	.8-1.1	
460	373-746	449-1119	746-2237	1491-3728	.8	
510		559-1491	746-2237	1491-3728	.8	42.3-49.3

Flight Width (in)	hp required for various lengths (ft) (5-20)	(21-30)	(31-40)	(41-50)	Flight Speed (fpm)	Approximate Capacities (bu/hr)
5	¼-½	3/4			290-450	300-500
6*	¼-3/4	3/4-1			290-450	500-600
8*	½-1	½-1	3/4-1		150-365	400-600
14	3/4	1	1½-3	2	150-225	
18	½-1	3/4-1½	1-3	2-5	150	
20		3/4-2	1-3	2-5	150	1200-1400

Based on Purdue Agric. Exp. Sta. Bull. 740
*Double these power requirements for high capacity bulk feed handling.

TABLE 2.1.6 CONVEYOR CHAIN TYPE AND USE

Type of Chain	Use	Example
Malleable detachable) Steel detachable)	Light, intermittent use	Portable grain elevator
Pintle chain	Medium duty	Processing equipment
Roller chain	For rolling contact, less friction, free of abrasive material	Baled hay drag
Combination chain	Heavy duty - combines better quality of other types	Mixed feed conveyor hay drag

2.1.4 Bunk Feeder Conveyors

Chain and flight conveyors have been modified by some manufacturers to serve as feeders for beef and dairy livestock.

An evaluation of mechanical bunk feeders, incorporating chain conveyor and auger conveyor designs, which are supplied by several farm equipment manufacturers was reported by Bellman (1) in 1975. A summary of his report follows:

The feed rations most difficult to distribute evenly are those containing hay silage followed by high moisture grain. Good mixing of a ration is required prior to supplying a tapered bed feeder since little mixing occurs on this conveyor. The distribution pattern of feed spread by a single and double tapered feeder depends on the condition of the feed. Compacted and unfluffed silage causes the greatest non-uniformity of ration spread in the bunk.

No correlation was evident between efficiency and power use and moisture content or degree of fineness. As the feeder or bunk filled, power used increased to a maximum, for auger, chain and paddle, horizontal belt, tapered bed and the oscillating bunk feeder, but remained essentially constant with overhead oscillating units. Overhead oscillating and tapered feeders are the most efficient in use of power. For auger type feeders, feed rations containing all or part hay silage appear to require proportionally more power to distribute than for other materials. This does not hold true for other types of feeder units.

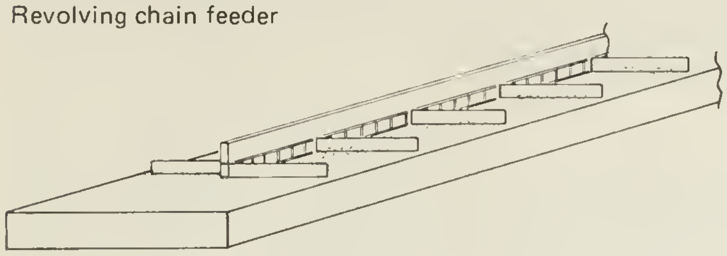
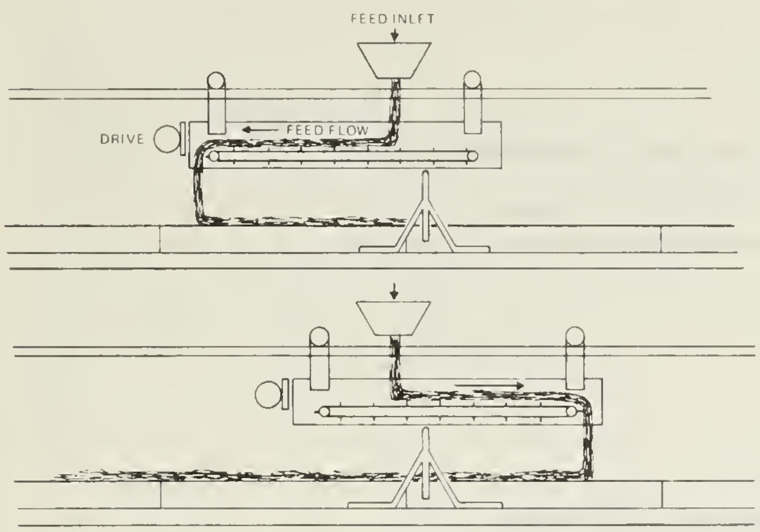
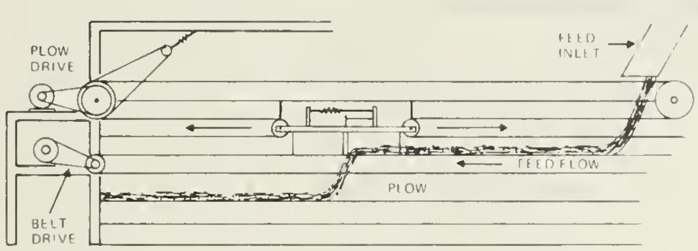
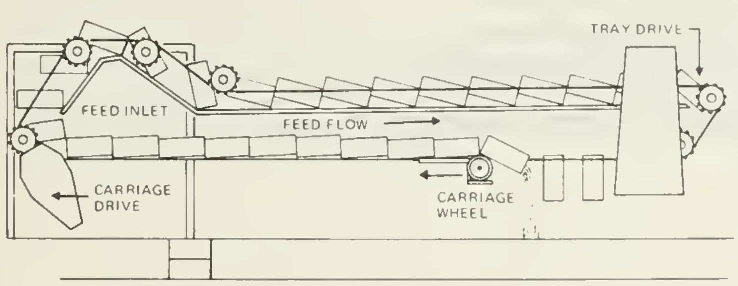
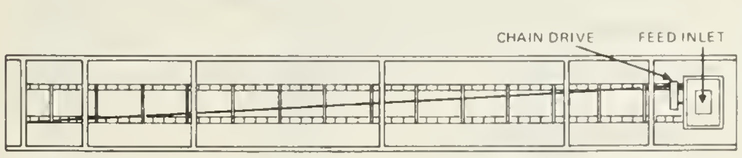
Feeders that do not have augers tend to lay the ration in the feed bunk as delivered to the feeder. Thus better mixing must be provided prior to the feeder in order to blend the ration ingredients in the desired proportions. Several types of bunk feeders are illustrated in Figure 2.1.5.

2.1.4.1 Selection characteristics

In selecting a bunk feeder consider,

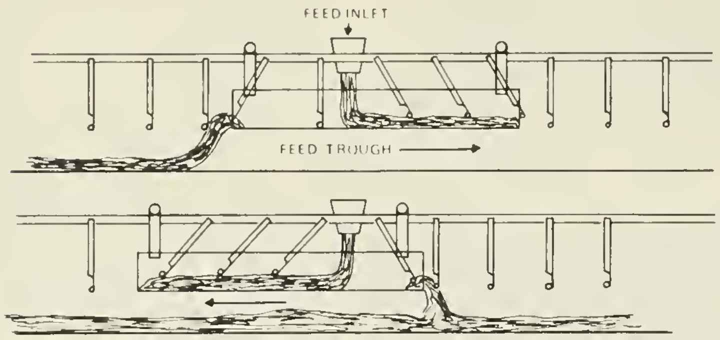
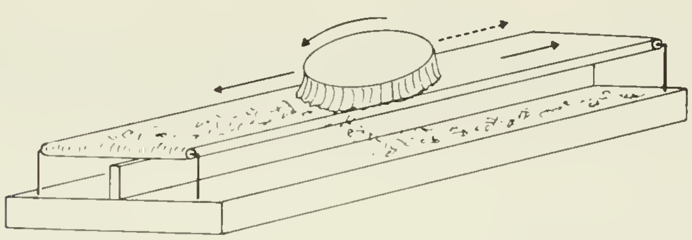
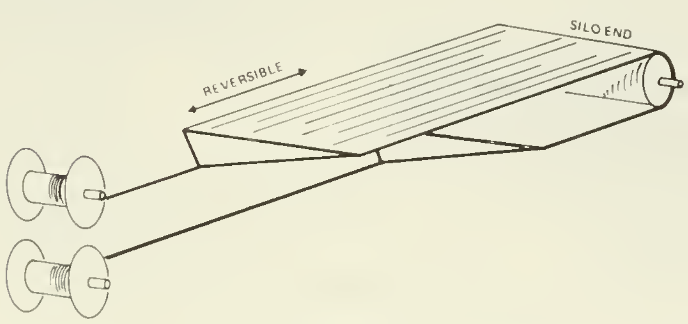
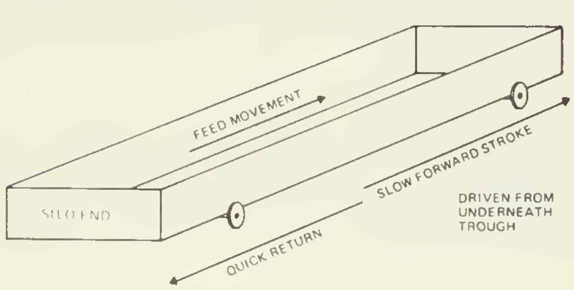
a) Design and operational characteristics relative to the length of time required to feed the last animal.

FIGURE 2.1.5. Varieties of Chain and Belt Bunk Feeders

Type of Feeder	Comments	Approx. hp for 100-ft bunk	No. pens normally serviced
Revolving chain feeder 	Similar to a barn cleaner. Often filled from one end with a front-end loader. Can be used in circular bunks at base of silo or in rectangular bunks. Requires more power than most chain or belt bunk feeders.	1½-3	2+
Reciprocating feeder 	Feeder is half the bunk length. Feed inlet is at the bunk's center. Conveyor travels about 50 ft/min and frequently reverses direction to provide any desired amount of feed over entire bunk. For best performance, requires frequent oiling and adjustment of the chain.	3/4-1	2
Plow-type felt feeder 	An endless belt with a blade or plow that automatically reciprocates between ends of bunk. Belt travels at about 250 ft/min and loaded side is always under tension. Plow travels at about 1/3 the belt speed.	1-1½	2+
Tray-type feeder 	Designed so that exactly the same feed placed in each tray can be dropped in selected portions of the bunk. As trays are filled and move away, carriage wheel rides to a predetermined point with the full lead tray. When desired, the drive pulls the carriage wheel back, dumping each tray successively. Magnetic switches, placed at preselected points along the feeder supports, allow automatic filling of several sections with different rations.	1½	2+
Taper-bed chain feeder 	Feed moves over a tapered board and is dropped off over the entire feed bunk length on a proportionate basis. With dry feed, wind may be a problem.	1½	1

(continued)

FIGURE 2.1.5. Concluded

Type of feeder	Comments	Approx hp for 100-ft bunk	No. pens normally serviced
Baffle-type sweep feeder 	Similar to tray feeder, but has fewer mechanical parts and less flexibility.	1-1½	2+
Belt feeder with brush 	Works like a plow-type belt feeder, but belt travels slightly faster. Feed is discharged by a rotating brush powered by an instantly reversing electric motor.	1½-2	2+
Reversible belt feeder 	Belt, pulled by cables at the desired speed, is filled as it moves away from feed source. Cattle feed directly from the belt. On next feeding, drive is reversed and uneaten feed is dumped off the belt before refilling.	1	1
Shaker trough feeder 	Large metal trough oscillates, moving feed to far end of bunk on forward stroke. Trough is filled progressively and cattle eat from it. Fairly costly, as bunk plus drive and suspension mechanism must be purchased.	3	2

b) The susceptibility of feeders to the various aspects of weather.

c) The characteristics of feeds to be fed and the flexibility of a particular feeder being able to handle a wide range of feeds, such as hay silage, and high moisture corn.

d) The amount of adjusting required when a ration change is made.

e) The flexibility and numbers of different lots that can be fed.

f) The flexibility to an expanded feeding situation.

2.1.5 Apron Conveyors

Apron conveyors have a moving platform or apron on which the material is carried. In agricultural use these conveyors are frequently used in the bottom of wagons,

trailers and flat-bottom storage bins. The material used may be wire mesh, rubberized material or heavy canvas.

Packaged materials may be handled on apron conveyors equipped with cross slats of wood or metal. These conveyors may operate on inclines up to 35 to 40°. Conveyor speed may be any value up to approximately 0.5 m/s (100 fpm).

2.1.6 Belt Conveyors

A belt conveyor is an endless fabric, rubber, plastic, leather or metal belt operating over suitable drive pulleys, tail end pulleys, bend terminals, and belt idlers and used for handling bulk materials, packages or objects placed directly on it.

Where high capacity and long distance movement of bulk materials are required the belt conveyor has a decided advantage. They also have a low noise level, high mechanical efficiency, minimum material damage and a long service life. Their disadvantages are limited angles of elevation and a high first cost.

Other factors to be considered are a) straight line plans are required; b) angle of inclination is limited to about 35° without special modifications; c) the carrying capacity is influenced by the way material is piled on the belt.

For carrying bulk materials the capacity can be increased by troughing the belt over inclined outer idlers. These outer idlers are tilted at 25-30° as shown in Figure 2.1.6.

The effective cross sectional area "a" of material on a troughed belt can be estimated from $w^2/12$ where "w" is the belt width. For very coarse or blocky material that does not tend to spread out on the belt, the cross sectional area can be calculated from $w^2/10$ (2). The belt capacity can then be calculated from equation [1]. The coefficient of friction for the bearings of the idlers can be taken as 0.03. The mass of the moving components in kg can be estimated as $Mp = 60w$, where "w" is in meters, if manufacturers' data is not readily available. To allow for friciton in the end pulleys an additional length of 45m (147 ft) is usually added (3).

When considering the power to elevate the material only the conveyor length is used not the length plus 45.

Belt conveyor designs thus consist of two basic types; the flat belt, and the troughed belt.

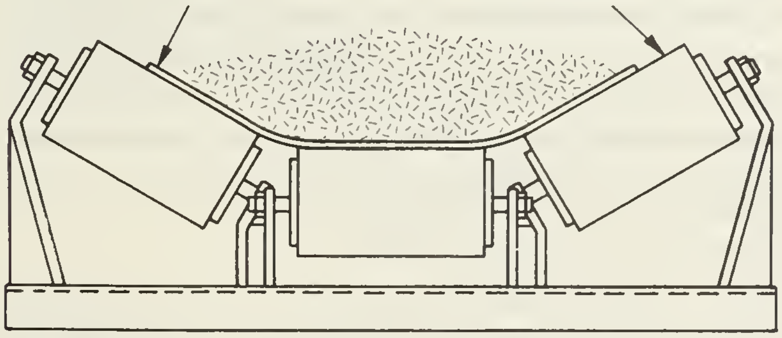


FIGURE 2.1.6 Belt Troughing Idlers

Some agricultural applications for each are:

Flat belt conveyors –

- i Sorting tables for fruit and vegetables.
- ii Low capacity metering in feed mills.
- iii Conveying packaged material such as potatoes and carrots.
- iv Egg gathering in cage laying poultry buildings.
- v Bunk feeder distributors.

Troughed belt conveyors –

- i Grain, weed seeds etc. where self cleaning is required.
- ii Hay wafers.
- iii Silage.
- iv Fertilizer.

2.1.6.1 Components

(1) **The belt.** The number of plys and weight of cotton duck in a belt, depends on the belt width and weight of duck used (see Figure 2.1.7). The belt must have sufficient plys to train properly over the pulleys and support the material to be conveyed. Belt suppliers usually express the quality of cotton duck in 5 grades (28 oz to 48 oz) for a piece 36 in long by 42 in wide. This fabric is impregnated with rubber or p.v.c. The strength of the belt is due to the tension carried by the plys of fabric. The permissible working stress is 5.25 kN/m width/ply (30 lb/in width/ply).

(2) **Idler pulleys.** To prevent undue sag of the loaded belt idlers are spaced 1.2 to 1.5m (4 to 5 ft) apart for a belt width up to .45m (18 in). If unit loads in rigid containers are to be conveyed up an incline closer spacing of idlers will be required to prevent the load from undulating and losing contact with the belt and allowing slip to occur.

(3) **Drive mechanism.** Drives should be designed for maximum conditions such as peak loads and maximum speeds. The drive should be located at the head end or discharge end, although for short conveyors locations near the tail end are satisfactory. Snub pulleys to increase the angle of wrap over 180° on the drive pulley are not required except for very long installations, which are not likely to occur in agricultural situations.

(4) **Tension mechanism.** On short conveyors proper belt tension is maintained by screw type take-ups and on long conveyors gravity take-ups are frequently used. Tension should be just enough to prevent the loaded belt from slipping on the drive pulley.

(5) **Feeding mechanism.** Material may be fed onto the belt at any point along its run. It can be done by hand or by a mechanical feeder that provides a continuous steady flow. A simple funnel with a gate valve or if the material does not flow freely, then a screw, apron or vibrating mechanism may be required.

(6) **Discharge mechanism.** The simplest method is over the head end of the belt. Scrapers or plow-type devices may be placed diagonally over the belt to discharge the load to one or both sides. Tripper mechanisms are also available but likely to be too expensive for agricultural applications.

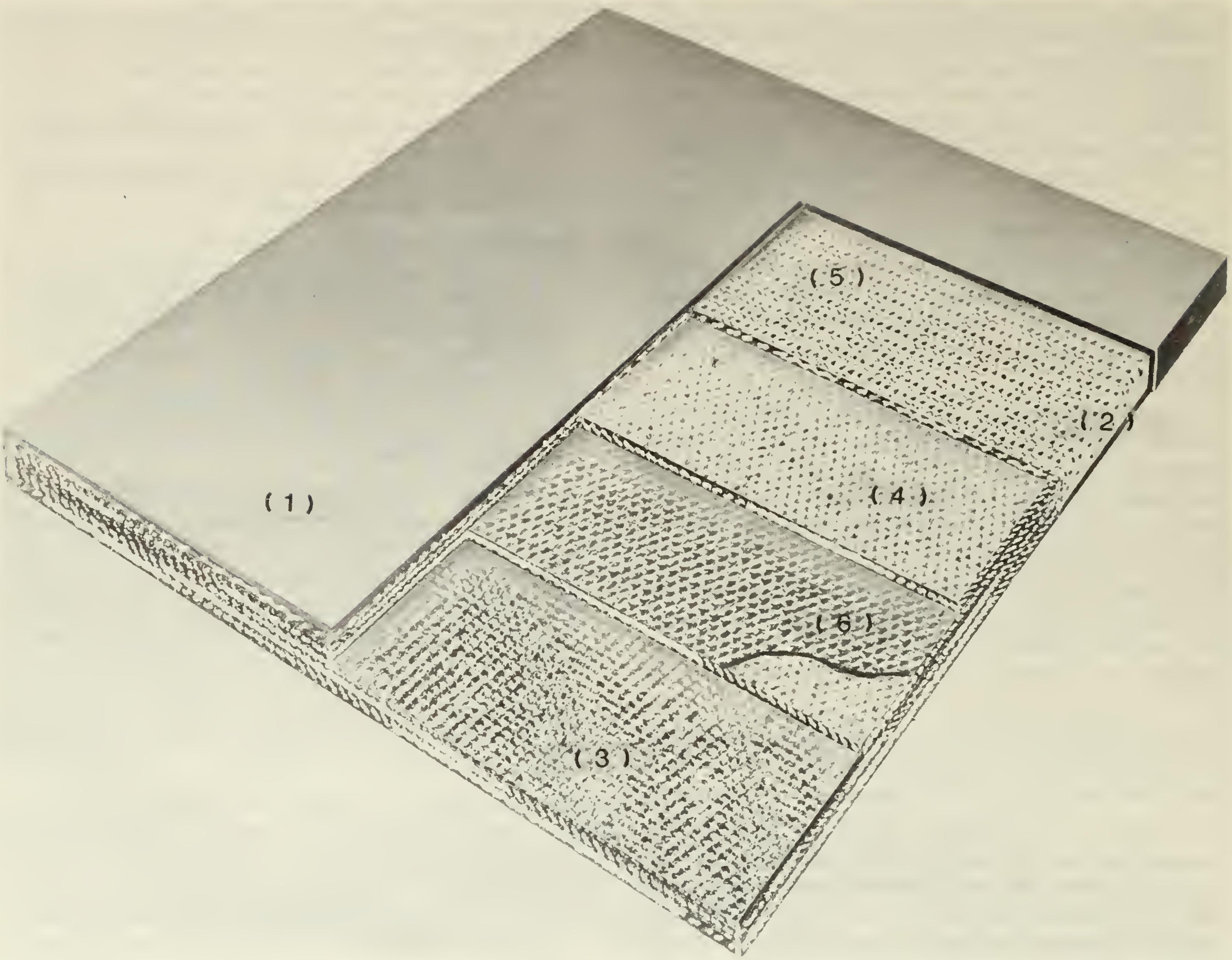


FIGURE 2.1.7 Cross Section of Conveyor Belting Construction. Courtesy: F.B. Goodrich Canada Ltd.

1. Cushion cover
2. Flexible bonded edge
3. Rubber friction or coating of rubber between layers of fabric
4. Heavy plies of burled fabric
5. Breaker fabrics
6. Rubber skim coats

TABLE 2.1.7 FEED CONVEYOR EFFICIENCES

Conveyor Type	CONVEYOR EFFICIENCY (kg/kwh)	(lb/kwh)
Auger	2900	4800
Chain and Paddle	2000	3100
Overhead Oscillating	5900	9800
Horizontal Belt	2700	4400
Tapered Bed	3300	5400

(7) **Belt cleaners.** If sticky or moist material such as beet pulp is conveyed, then a belt cleaner will be necessary to prevent build up on the return idlers. This cleaning may be done with a scraper or rubber or steel strip held against the belt, a rotary brush, or a high pressure water jet. Rotary brushes are good cleaners but the bristles will wear down rapidly. Depending on the circumstances water may contaminate or be deleterious to the material being conveyed.

(8) **Magnets.** Electromagnets may be suspended over the moving material on the belt to remove tramp iron that may be present. A more expensive method is to build the magnet into the head pulley. The material must be spread as thinly as possible for these methods to be effective.

Some manufactureres have placed the top strand of the belt in a tube for handling grain and ground feeds. The purpose of this is to shield the material conveyed from wind when the conveyor is used outside (see Figure 2.1.8).

2.6.2 Example problem

A troughed belt conveyor 13.7m (45 ft) long is inclined at an angle of 30°. The belt is 0.3m (1 ft) wide and is to

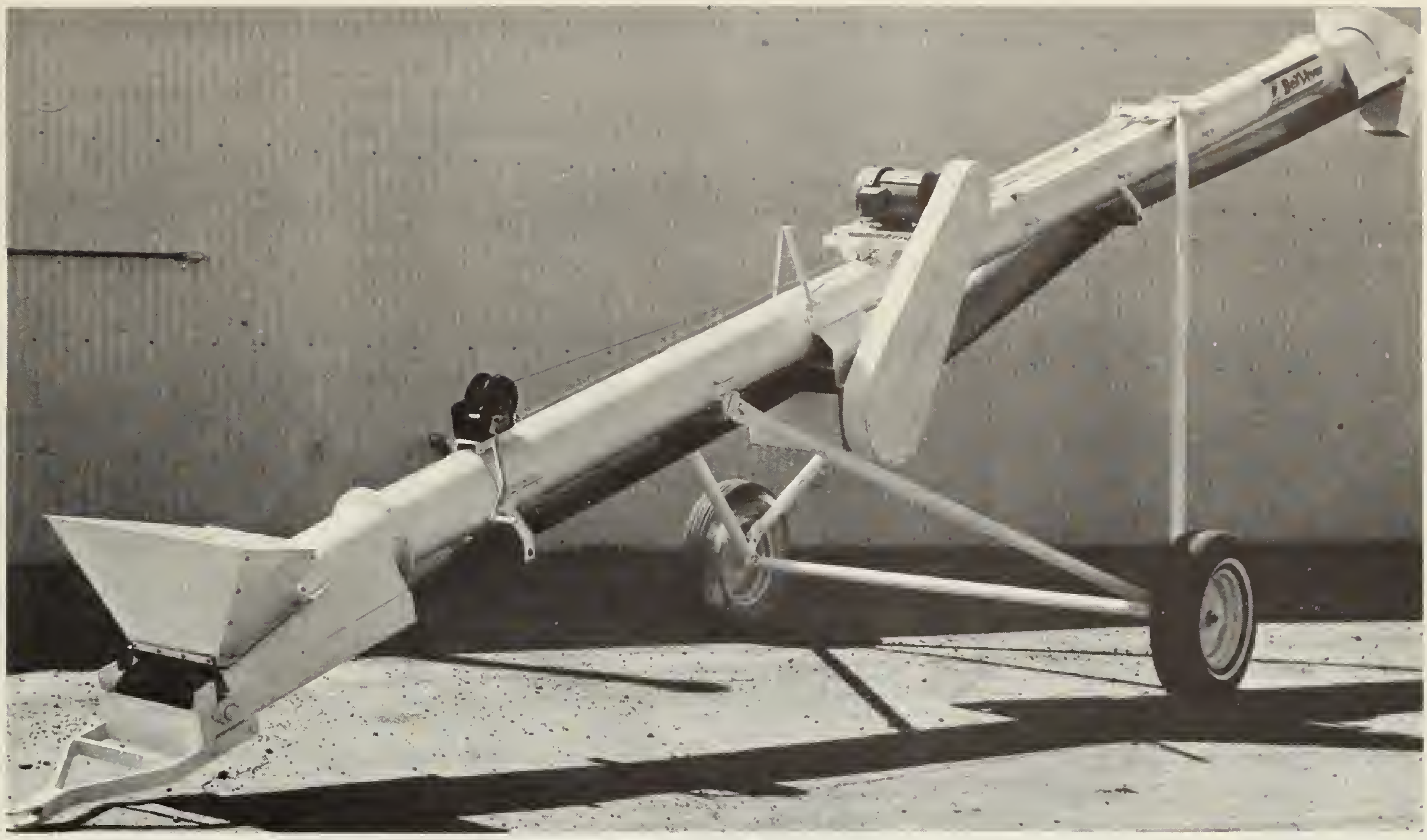


FIGURE 2.1.8 Belt-in-a-tube Conveyor. Courtesy: Speed King Mfg. Co., Inc.

TABLE 2.1.8 EVALUATION OF FEEDERS ACCORDING TO RELATIVE TIME REQUIRED TO FEED THE LAST ANIMAL

Feeder Type (1)	Feeding Characteristic (2)	Influence of Rate of Input on Last Animal (3)	Influence of Bunk Length on Last Animal (4)
Open auger	P(s)	Large	Large
"J"-trough	S	None	None
"U"-trough	S	None	None
"C"-trough - slot	P(f)	Small	Small
- roll-over	S	None	None
Chain & paddle	P(s)	None	Large
Overhead oscillating - chain	P(f)	None	Small
- belt	P(f)	None	Small
- sweep	P(f)	None	Small
Horizontal belt - brush	P(f)	None	Small
- bar	P(f)	None	Small
Tapered bed - single	P(f)	None	Small
- double	P(f)	None	Small
Oscillating bunk	P(s)	Small	Large

Explanation of Table 2.1.8

Column (1) - Feeder Type - evaluation given only for those feeders tested.

Column (2) - Feeding characteristic - because of design and operating characteristics feeders vary in the way in which feeding occurs: P(s) = slow progressive feeding from the input end of the bunk outward. P(f) = fast progressive feeding from the input point outward. S = simultaneous feeding from one end of the bunk to the others.

Column (3) - Influence of Rate of Input on Last Animal - evaluation of the degree to which the rate of feed input to the feeder influences length of time last animal waits for some feed to be available.

Column (4) - Influence of Bunk Length on Last Animal - as in Column (3) - for length of bunk.

TABLE 2.1.9 EVALUATION OF ITEMS AND CONDITIONS WHICH AFFECT FEEDER PERFORMANCE

Feeder Type	Effects of Weather: Wind	Rain	Freezing	Snow	Effects of Feed Characteristics: Type	Fineness	M.C.	Tolerance of Ration Change
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Open auger	No	No		Some	S,G,CDH	F&C	W	Some
"J"-trough	Some	No	Yes	No	S,G,CDH	F&C	W	Large
"U"-trough	Some	No	Yes	No	S,G,CDH	F&C	W	Large
"C"-trough - slot	Some	No	Yes	No	S,G	F&C	W	Little
- roll-over	Some	No	Yes	No	S,G	F&C	W	Large
Chain & paddle	No	No	Yes	Yes	S,G,DH	NE	W	Large
Overhead oscillating								
- chain	Yes	No	Yes	No	S,G,CDH	NE	NE	Large
- belt	Yes	Some	Yes	No	S,G,CDH	NE	NE	Large
- sweep	Yes	No	Yes	No	S,G	C	NE	Large
Horizontal belt - brush	Some	Yes	Yes	No	S,G,CDH	NE	W	Large
- bar	Some	Some	Yes	No	S,G,CDH	F	NE	Large
Tapered bed - single	Yes	Some	Yes	No	S,G	C	W	None
- double	Yes	Some	Yes	No	S,G	C	W	None
Oscillating bunk	No	Some	Some	Yes	S,G,DH	NE	W	Large

Explanation of Table 2.1.9

Columns (2-5) - Effects of Weather - effects of wind, rain, freezing temperatures and snow on the performance of the feeder and its ability to properly place feed in the bunk; No = no effect; Some = some effect; Yes = considerable effect.

Columns (6-8) - Effects of Feed Characteristics - effects of type of feed, fineness of the feed, and its moisture content; S - silage; G - grain; CDH - chopped dry hay; DH - dry hay (long and short); F = finely ground; C - coarse; NE - no effect; W - wet, or of high moisture content.

Column (9) - Tolerance to Ration Change - an evaluation of a feeder's ability to handle different feed rations without the necessity of making adjustments to make it perform satisfactory.

deliver rapeseed at 2.5 kg/s (9.9 tons/hr). Determine the power requirement to handle this material under the given conditions.

Solution

From Section 7.1 the bulk density of rapeseed averaged 705 kg/m^3 (44 lb/ft^3). From Section 2.1.6 the effective cross sectional area can be estimated from

$$a = \frac{w^2}{12}$$

$$a = \frac{(.3)^2}{12} = .0075 m^2$$

From equation [1]

$$V = \frac{T}{ab} = \frac{2.5}{.0075(705)} = .47 \text{ m/s}$$

From equations [2] and [3] and using the recommendations of section 2.1.6 the coefficient of friction for the idlers is .03. A length L_c of 45m is added to compensate for friction in the end bearings and the mass of moving components Mp can be estimated as 60w.

$$\begin{aligned} P_e &= M_p (L + L_c) g \mu_p V \\ &= 60(.3)(13.7 + 45)(9.81)(.03)(.47) \\ &= 146 \text{ W.} \end{aligned}$$

Since the material is carried on the belt rather than being dragged as in a flight conveyor the frictional resistance to be overcome will be due to the increased normal force on the idlers and drive pulley.

$$\begin{aligned} P_m &= M_m (L + L_c) g \mu_p V \\ &= 705(.0075)(13.7 + 45)(9.81)(.03)(.47) \\ &= 43 \text{ W.} \end{aligned}$$

The power to elevate the material can be calculated from equation [5]. The material is elevated

$$\begin{aligned} h &= L \sin 30^o \\ &= 13.7 \sin 30^o \\ &= 6.86 m \end{aligned}$$

$$\begin{aligned} P_r &= T g h \\ &= 2.5(9.81)(6.86) \\ &= 168 \text{ W.} \end{aligned}$$

The total power required then is

$$\begin{aligned} P_t &= P_e + P_m + P_r \\ &= 146 + 43 + 168 \\ &= 357 \text{ W or .5 hp.} \end{aligned}$$

Providing allowances for losses in the drive assembly, the motor and surges in material flow can result in an overall efficiency of 45 to 65 percent (3).

Therefore motor power required is

$$\frac{357}{.55} = 649 \text{ W or } .9 \text{ hp.}$$

Therefore choose a 1 hp electric motor. For gasoline engine selection a factor of two times the electric motor horsepower is often suggested. Therefore in this example a gas engine of 2 hp rating should be recommended.

TABLE 2.1.10 EVALUATION OF THE FLEXIBILITY AND ADAPTABILITY OF TYPES OF FEEDERS TO MEET CHANGING SITUATIONS

Feeder Type	Number of Lots Possible	Adaptability to expansion	Maximum Recommended Bunk (m)	Length (ft)
(1)	(2)	(3)	(4)	
Open auger	1	Easy	61	200
"J"-trough	2	Moderately Easy	46	150
"U"-trough	4	Moderately Easy	61	200
"C"-trough - slot	2	Moderately Easy	46	150
- roll-over	2	Easy	46	150
Chain & paddle	1	Easy	46	150
Overhead oscillating - chain	2	More Involved	61	200
- belt	2	More Involved	76	250
- sweep	2	More Involved	46	150
Horizontal belt - brush	6-8	Moderately Easy	61	200
- bar	6	Moderately Easy	75	245
Tapered bed - single	2	Moderately Easy	55	180
- double	1	Moderately Easy	(not available)	
Oscillating bunk	1	Easy	31	102

Explanation of Table 2.1.10

Column (2) - No. of Lots Possible - maximum number of lots of cattle that can each be fed with a different ration using the one feeder.

Column (3) - Adaptability to Expansion - an evaluation of the ease with which a feeder may be lengthened to accommodate more cattle.

Column (4) - Maximum Recommended Bunk Length - maximum length of one main drive unit as recommended by manufacturers of each type of feeder.

2.1.6.3 **Capacity guide**

The capacity of belt conveyors as described previously is a function of belt width, speed and density of material handled. Table 2.1.11 shows a capacity guide adapted from the Midwest Plan Service (8). It is based on uniform loading of the belt operating at 0.5 m/s (100 fpm).

TABLE 2.1.11 BELT CONVEYOR CAPACITY GUIDE*

	TROUGHED BELTS		FLAT BELT	MAXIMUM SPEED	
Belt Width	560 kg/m^3 Material	800 kg/m^3 Material	800 kg/m^3 Material	Fine Grind	Whole Grain
(mm)	(kg/s)	(kg/s)	(kg/s)	(m/s)	(m/s)
300	2.0	2.9	1.4	1.5	1.8
350	3.0	4.0	1.8	1.5	2.0
410	3.7	5.3	2.4	1.5	2.3
460	4.6	6.5	2.9	2.0	2.3
510	5.9	8.4	3.8	2.0	2.3
610	8.6	12.3	5.5	2.5	3.1

	TROUGHED BELTS		FLAT BELT	MAXIMUM SPEED	
Belt Width	35 lb/ft^3 Material	50 lb/ft^3 Material	50 lb/ft^3 Material	Fine Grind	Whole Grain
(in)	(tons/hr)	(tons/hr)	(tons/hr)	(ft/min)	(ft/min)
12	8.1	11.5	5.7	300	350
14	11.8	15.8	7.1	300	400
16	14.7	21.0	9.5	300	450
18	18.1	25.9	11.6	400	450
20	23.4	33.4	15.0	400	450
24	34.3	49.0	22.0	500	600

*Based on belt operating speed at .5 m/s (100 ft/min).

2.1.7 REFERENCES

1. Bellman, H.E. 1975. An evaluation of mechanical bunk feeders for silage and grain feeding for cattle. Canada Agriculture ERS Contract OSW4-0161 Report.
2. Bolz, Harold A. 1958. Materials Handling Handbook, Ronald Press, New York.
3. Brook, N. 1971. Mechanics of Bulk Materials Handling, Batterworth and Co. London.
4. Conveyor Equipment Manufactures Assoc. Technical Committee. 1958. Terms and conveyor definitions, Conveyor Equipment Manufacturers Assoc.
5. Harrington, C.C. 1952. Materials handling manual, Conover-Mast Publications Inc.
6. Jones, L. 1971. Mechanical handling with precision conveyor chain. Hutchinson of London.
7. Keller, H.C. 1967. Unit-load and package conveyors — application and design, Ronald Press Co., New York.
8. Midwest Plan Service. 1975. Structures and environment handbook, Midwest Plan Service, Iowa State University, Ames, Iowa.
9. Simmons, N.O. 1963. Feed milling, Leonard Hill Ltd.